NASA TT F-9736

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Translation of "Über die Schwankungen des Chloridgehaltes im Blut, Harn und Schweiss bei Muskeltätigkeit." Arbeitsphysiologie, Vol. 2, pp. 461-473, 1930.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON JANUARY 1966

ON THE CHANGES IN THE CHLORIDE LEVELS IN THE BLOOD, URINE, AND SWEAT ASSOCIATED WITH MUSCULAR ACTIVITY. Report No. 1*

A.F. Koriakina, E.B. Kossowskaja and A.N. Krestownifoff

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Studies were conducted on the chloride levels in the blood, urine and sweat of individuals after various degrees and types of muscular activity. Two levels of blood chloride level variation were discernible: it rose shortly before the start or after the cessation of a short period of work, and dropped after a longer period of exertion. The urine chloride level generally dropped, however the amount of chloride in the urine usually increases at the start of the activity. The magnitude of the drop in blood and urine chlorides stands in a direct relation to the intensity and duration of exertion. Muscular activity as a rule caused the sweat chlorides to rise. When the blood chloride level was low, no chlorides were eliminated via sweat. Finally, chloride metabolism during muscular activity was related to the general water and salt metabolism. One thing that does appear certain is that the release of chlorides through perspiration requires a certain blood chloride level, and this minimum level varies greatly. **/32

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The problem of changes in chloride levels has been dealt with in numerous papers.

Some authors (Rakestrew, Peters, Eisenmann and Lee, Talbert, Finkle and Silvers, Ewig and Wiener, Appolonoff and Prikaldowitzky) studied the blood only, others (Talbott, Folling, Henderson, Dill, Edwards and Berggreen) the urine, still others (Burchardt, Snaper and Grunbaum) the sweat or muscles (Embden).

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*A paper presented at the 127th meeting of the Russian Physiological Society on October 31, 1929. Since that presentation, the authors have continued their observations on soccer players of a local institute (see Tables 1 and 5). A depressed chloride level in the blood (135-273 mg %) was noted in the players prior to the soccer match held on November 2, 1929. At the end of the game, the sweat of 6 of the 10 players tested was found to contain no chlorides.

**/Numbers in the margin indicate pagination of the original foreign text.

A paper by Talbert and Haugen deals with the chloride levels in the blood, urine, and sweat during heating of the organism and in the course of work.

One may conclude from these studies that as work is done the chloride level in the blood either rises or remains unchanged, dropping in the urine and rising in the sweat (the amount of chlorides present in the latter cases increases by 2-4 g). In the blood there occurs an exchange between the plasma and erythrocytes; an exchange between the muscle matter and tissue fluid occurs in the muscles. A relationship between the chloride levels in the sweat and urine has not been established, although such a relationship does exist between the amount of chlorides present in the blood and sweat.

Our study on the participants of a 144-km bicycle race revealed a drop in blood and urine chlorides and a rise in the chloride level in the sweat. The surprising drop in the chloride level of the blood impelled us to study the changes in the chloride levels in the blood, urine, and sweat with other types of muscular activity, i.e., a 3-km womens' foot race, 13.5-km and 28-km mens' /462 foot races, a soccer game, and 45-60 minute workouts on fixed trainer bikes.

We also posed for ourselves the task of investigating the relationship between the chloride distribution in the blood and urine on the one hand, and the elimination of chlorides through perspiration on the other.

The studies were performed on participants in the annual 3-, 13.5-, and 28-km foot races held in September under the auspices of the magazine Spartak and the newspaper Krasnaya Gazeta, on players in soccer matches between a local institute and other higher schools (only the members of the local team took part in the study), and on students and staff members of our laboratory who worked out on fixed trainer bikes.

The blood samples were drawn from the finger in most cases, and from the median cubital vein in the case of the bicycle workouts. Chlorides were determined by the Volhard technique. The sweat samples were taken from the subjects' sweatshirts. The results for the soccer players and runners are given in Table 1. Those for the bicycle workouts appear in Table 3.

As we see from the figures in Table 1, the average chloride levels of the blood and urine following the 13.5- and 28-km foot races as well as following the 144-km bicycle race dropped more than after the foot race over 3 km or the soccer game, unmistakeably pointing to their relationship with the intensity /463 and duration of effort in these sports: the greater the intensity and duration of muscle activity, the more marked the drop in the amount of chlorides present in the blood and urine. The chloride level of the sweat was highest (on the average) in the 13.5-km foot race, falling with the 28-km foot race, the 3-km foot race, the 144-km bicycle race, and the soccer game, in that order.

Comparing the changes in the chloride content of the blood associated with intense and prolonged muscular activity, we see that the largest drop occurred in the cyclists and the smallest in the 13.5-km foot race runners; the drops in the case of the 28-km foot race runners lie between these two extremes. The size of the drop is therefore seen to correspond completely to the expenditure of energy associated with each activity. In the case of the soccer players the amount of blood chlorides dropped an average of 4 mg, while in the case of the 3-km foot race the chloride level exhibited no change whatever. The latter fact is related to the brevity of muscular exertion (16-18 min). The average value in the case of the soccer players also exhibits no marked change due to the varying exertion of individual players.

The chloride level of the urine dropped the greatest amount (as much as 222.9 mg) for the 13.5-km foot race runners, followed by the 144-km race

TABLE 1. AVERAGE VALUES

Test dates (1929)	Nature of competition	Duration of Competition	No. of persons tested	Chloride level: in blood, mg %, bef.	aft.	Diff.	in urine, mg %, bef.	aft.	Diff.	in sweat, mg	A	B
Aug. 11	144-km bicycle race	6 h, 27.5 sec.	13	309	279	-30	850	643	-207	328	700	1.5
Sept. 8	13.5-km mens' foot race	55 min. 48.2 sec.	11	251	234.7	-16.3	728.6	505.7	-222.9	539	737	1.8
Sept. 22	28-km mens' foot race	2 h, 5 min. 34 sec.	26	246.9	225.4	-21.5	641	456.5	-184.5	446.5	1156.5	1.4
Sept. 8	3-km womens' foot race	16 min., 14.5 sec.	9	258.7	258.5	- 0.2	766	647.5	-118.5	373.5	668	1.0
Sept. 6 to Nov. 2	soccer games	1 h, 30 sec.	72	308.7	305.7	- 3	915.5	793.6	-121.9	213.6	423.4	-

KEY: A - Lactic acid content of sweat, mg (per sweatshirt).

B - Weight loss, kg.

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TABLE 2. BREAKDOWN OF RESULTS IN TABLE 1

Subject's initial	Duration of competition	Chloride level: in blood mg % before	in blood mg % after	Diff.	in urine mg % before	in urine mg % after	Diff.	Sweat, mg	A
		Sept. 8, 1929. 13.5 km							
D.	50 min. 46.0 sec.	.	.	.	.	.	.	860	860
F.	52 min. 32.0 sec.	248	238	-10	958	674	-284	320	280
K.	53 min. 25.0 sec.	276	260	-16	994	.	?	148	380
S.	53 min. 26.0 sec.	.	.	.	.	958	?	560	1320
J.	53 min. 35.0 sec.	.	.	.	.	461	?	125	250
N.	53 min. 57.0 sec.	.	.	.	744	514	-230	510	900
Tsch.	59 min. 34.0 sec.	.	.	.	461	426	- 35	862	260
K.	58 min. 22.0 sec.	237	213	-24	738	355	-383	1200	400
R.	59 min. 0.7 sec.	241	213	-28	994	834	-160	596	1620
Jud.	58 min. 30.0 sec.	.	.	.	674	432	-242	282	1220
K.	59 min. 25.0 sec.	213	200	-13	834	403	-431	452	620
P.	58 min. 10.0 sec.	291	284	- 7	426	408	- 18	.	.
		Sept. 8, 1929. 3 km							
D.	14 min. 16.9 sec.	.	.	.	712	568	-144	145	1640
K.	15 min. 35.0 sec.	.	.	.	.	.	.	365	220
B.	16 min.	213	237	+24	958	958	0	526	620
Sch.	16 min. 15 sec.	291	284	- 7	.	.	.	125	240
B.	16 min. 27.0 sec.	262	237	-25	710	656	- 54	320	280
K.	16 min. 39.0 sec.	.	.	.	.	.	.	820	1680
K.	16 min. 44.0 sec.	276	.	.	710	674	- 36	140	440
K.	17 min. 0.3 sec.	259	.	?	.	.	.	145	280
M.	17 min. 22.0 sec.	269	276	+ 7	.	.	.	660	610
K.		284	.	?	674	674	0	.	.
W.		269	.	?	844	355	-489	.	.

KEY: A - Lactic acid content of sweat, mg.

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TABLE 2a

Subj. initial	Duration of competition	Weight loss	Chloride level: in blood mg % before	in blood mg % after	Diff.	in urine, mg before	in urine, mg after	Diff.	Sweat, mg	A
		Sept. 22, 1929. 28 km								
M.	1 h. 49 min. 19.3 sec.	1.3	213	168	- 45	816	642	- 176	300	280
K.	1 h. 54 min. 49.3 sec.	.	259	184	- 75	.	.	.	.	.
Sch.	1 h. 54 min. 18.8 sec.	.	220	230	+ 10	.	.	.	330	680
J.	1 h. 54 min. 51.6 sec.	1.7	284	.	?	547	461	- 86	213	1240
K.	1 h. 55 min. 21.6 sec.	1.3	177	153	- 24	522	135	- 387	600	560
R.	1 h. 55 min. 17.6 sec.	1.3	260	248	- 12	944	451	- 493	530	1240
W.	1 h. 57 min. 46.5 sec.	.	.	.	.	461	426	- 35	241	1020
S.	1 h. 58 min. 4.0 sec.	0.9	.	.	.	710	419	- 291	696	1200
Z.	1 h. 58 min. 22.0 sec.	1.4	206	248	+ 42	912	373	- 539	333	740
M.	2 h. 2 min. 14.3 sec.	3.7	.	.	.	380	476	+ 94	656	1780
Jad.	2 h. 3 min. 57.5 sec.	1.4	.	.	.	841	640	- 201	639	1020
P.	2 h. 7 min. 20.0 sec.	21.	295	280	- 15	234	518	+ 284	213	600
E.	2 h. 8 min. 59.0 sec.	.	295	286	- 9	461	476	+ 15	248	1920
S.	2 h. 11 min. 57.5 sec.	0.5	270	159	-111	515	476	- 39	497	1000
Ch.	2 h. 12 min. 25.0 sec.	1.7	260	227	- 33	689	476	- 213	497	1760
G.	2 h. 16 min. 8.0 sec.	1.1	262	184	- 78	799	369	- 430	530	630
K.	2 h. 16 min. 28.5 sec.	1.8	.	238	?	461	561	+ 100	472	1460
M.	2 h. 17 min. 21.5 sec.	.	.	.	.	380	476	+ 96	656	1780
Ch.	2 h. 17 min. 37.8 sec.	.	280	264	- 16	965	476	- 489	369	1240
K.	2 h. 23 min. 22.5 sec.	1.2	355	.	?	1356	238	-1118	319	1780
R.	2 h. 27 min. 19.0 sec.	0.8	.	.	.	1012	444	- 568	620	1200
T.	1 h. 58 min. 46.5 sec.	2.4	206	230	+ 24	.	355	?	.	.
E.	1 h. 58 min. 9.0 sec.	1.9	220	296	+ 76	742	586	- 156	.	.
D.	2 h. 10 min. 18.5 sec.	1.1	250	230	- 20	273	284	+ 11	.	.
A.	1 h. 59 min. 11.0 sec.	0.3	216	242	+ 26	195	490	+ 295	.	.
D.	2 h. 30 min. 46.5 sec.	1.2	242	213	- 29	460	547	+ 87	.	.
A.	2 h. 6 min. 45.3 sec.	1.3	266	212	- 54	.	532	?	.	.
Z.	2 h. 37 min. 15.5 sec.	1.5	295	230	- 65	710	515	- 195	.	.

KEY: A - Lactic acid content of sweat, mg.

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TABLE 2b

Subj. initial	Subject's position in game	Chloride level: in blood mg % before	after	Diff.	in urine mg % before	after	Diff.	Sweat mg	A
			Sept. 6, 1929.						
P.	Goalkeeper	400	390	- 10	530	1000	+ 470	200	0
M.	Defense	•	440	?	•	780	?	•	•
P.	Defense	400	440	+ 40	660	590	- 70	310	0
Z.	Defense	400	390	- 10	520	1000	+ 480	90	120
K.	Defense	380	400	+ 20	1190	1480	+ 290	•	150
S.	Defense	350	380	+ 30	1070	820	- 250	370	•
T.	Offense	370	380	+ 10	1540	•	?	800	•
K.	Offense	•	380	+380	1230	1000	- 230	640	600
D.	Offense	370	380	+ 10	•	•	•	200	120
K.	Offense	400	390	- 10	970	1070	+ 100	•	•
A.	Offense	370	400	+ 30	•	780	?	120	120
			Sept. 12, 1929.						
P.	Goalkeeper	440	430	- 10	1270	1130	- 140	•	200
Tsch.	Defense	390	430	+ 40	1520	980	- 540	257	900
W.	Defense	•	380	?	1210	810	- 400	70	530
Z.	Defense	430	400	- 30	1830	1000	- 830	•	370
K.	Defense	390	390	0	1000	1070	+ 70	228	890
S.	Defense	360	390	+ 30	1870	750	-1120	456	560
F.	Offense	430	370	- 60	1530	800	- 730	310	510
B.	Offense	370	360	- 10	400	1060	+ 660	819	900
K.	Offense	460	430	- 30	810	940	+ 130	146	900
D.	Offense	310	390	+ 80	2140	•	?	245	620
K.	Offense	350	440	+ 90	1270	670	- 600	157	900
W.	Goalkeeper	400	440	+ 40	1020	800	- 220	222	900
M.	Defense	300	350	+ 50	980	1170	+ 190	193	730
M.	Defense	420	•	?	•	780	?	175	480
F.	Defense	390	•	?	•	•	•	99	710
B.	Defense	430	400	- 30	930	1130	- 200	900	900
W.	Offense	410	•	?	1240	1050	- 190	1053	•
D.	Offense	490	470	- 20	1170	760	- 410	1134	900
K.	Offense	390	340	- 50	800	650	- 150	•	•
M.	Offense	390	•	?	940	•	?	169	820
A.	Offense	410	350	- 60	1130	1183	+ 50	380	900
			Oct. 1, 1929.						
J.	Goalkeeper	322	262	- 60	919	688	- 231	•	•
M.	Defense	312	255	- 57	710	759	+ 49	11	120
G.	Defense	305	301	- 4	1000	1090	+ 90	327	650
A.	Defense	284	269	- 15	504	504	0	373	580
D.	Defense	284	234	- 50	1200	766	- 434	674	600

TABLE 2b (Continued)

Subj. initial	Subject's position in game	Chloride level in blood mg % before	after	Diff.	in urine mg % before	after	Diff.	Sweat mg	A
			Oct. 1, 1929 (Continued)						
O.	Offense	340	276	- 64	752	676	- 76	25	300
D.	Offense	212	259	+ 47	816	784	- 32	85	400
K.	Offense	212	284	+ 72	918	763	- 155	227	600
B.	Offense	256	262	+ 6	806	695	- 111	35	300
			Oct. 2, 1929.						
W.	Goalkeeper	259	268	+ 9	912	483	- 429	•	•
G.	Defense	284	268	- 16	728	529	- 199	•	180
Tsch.	Defense	302	334	+ 32	930	749	- 181	11	120
B.	Defense	305	254	- 51	788	721	- 67	273	500
S.	Defense	240	254	+ 14	628	667	+ 39	39	300
Tsch.	Defense	268	284	+ 16	•	586	?	21	250
T.	Offense	284	291	+ 7	1065	777	- 288	25	280
K.	Offense	284	268	- 16	•	756	?	131	600
W.	Offense	•	288	?	•	586	?	373	600
Sch.	Offense	234	255	+ 21	•	838	?	53	300
A.	Offense	304	240	- 64	571	479	- 92	145	•
			Oct. 8, 1929.						
P.	Goalkeeper	312	298	- 14	•	596	?	0	0
M.	Defense	308	301	- 7	•	•	•	0	0
Z.	Defense	240	212	- 28	685	706	+ 21	0	0
M.	Defense	254	240	- 14	692	699	+ 7	17	0
D.	Defense	319	291	- 28	692	685	- 7	0	300
O.	Offense	212	276	+ 64	695	695	0	39	80
K.	Offense	254	212	- 42	852	823	- 29	71	266
Ad.	Offense	330	298	- 32	564	571	+ 7	266	0
B.	Offense	326	291	- 35	695	685	- 10	0	0
P.	Offense	268	276	+ 8	475	557	+ 82	17	0

KEY: A - Lactic acid content in sweat, mg.

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TABLE 3. BREAKDOWN OF RESULTS IN TABLE 1

Date	initial	Subject's position in game	Chloride level in blood mg % before	Chloride level in blood mg % after	Diff.	Chloride level in urine mg % before	Chloride level in urine mg % after	Diff.	Sweat, mg	A
Nov. 2, 1929 T = 10°C	G.	Defense	135	231	+ 96	930	792	-138	0	400
	Tsch.	Defense	177	177	0	1118	564	-554	0	100
	S.	Defense	185	213	+ 28	951	600	-351	0	300
	B.	Defense	192	206	+ 14	1033	855	-178	305	900
	Tsch.	Defense	156	177	+ 21	575	561	- 14	7	600
	F.	Offense	135	99	- 36	802	774	- 28	0	300
	B.	Offense	142	114	- 28	1051	1225	+174	253	600
	Z.	Offense	273	213	- 60	966	699	-267	337	300
	Sch.	Offense	185	227	+ 42	-	-	-	0	-
	K.	Offense	216	163	- 53	866	337	-529	0	700

KEY: A - Lactic acid content, mg.

cyclists (207 mg), the 28-km foot race runners (184.5 mg), the soccer players (121.9 mg), and finally the women who ran the 3-km foot race (118.5 mg).

We found the chloride content of the sweat of the women participating in the 3-km foot race to be high, as might have been expected in view of the greater responsiveness of the female organism to exertion as compared with that of the male. In our view the higher chloride content of the sweat in the case /467 of the 13.5-km foot race as against the 28-km race was due to the higher intensity of muscular activity over the shorter distance, the longer race making greater demands on stamina.

As we see from Table 2, the values for individual participants in the competitions deviate somewhat from the average values presented earlier: following the 28-km race, the chloride level in the blood of five of the runners was higher than before the race; following the 3-km womens' race, the chloride level in the blood of two participants was found to have fallen, while that of two others had risen; in 28 of the 64 soccer players, the chloride level in the blood was higher than before the game, while that of the others had dropped.

As regards the urine chlorides, in the case of the 28-km foot race it fell in the majority of runners, but rose in the remaining eight; a drop in this level was observed for all participants of the 13.5-km race; in the 3-km foot race, no changes were observed in two cases; one of the cyclists in the 144-km bicycle race experienced an insignificant rise of the urine chloride level, while that of all the others fell. Two of the soccer players exhibited no change, 16 players a slight drop, and the remaining 37 cases a slight increase.

The chloride level in the sweat varied in the case of the 144-km bicycle race between 71 and 639 mg; the corresponding ranges for the 13.5-km foot race and 3-km foot race were 125-1200 mg and 140-820 mg, respectively. The sweat of

12 soccer players was found to be chloride-free, while the level in the sweat of the remaining team members varied from 11 to 1134 mg.

TABLE 4. CHLORIDE DISTRIBUTION IN THE BLOOD, URINE, AND SWEAT AFTER A SOCCER GAME

Subject's position in game	Chloride level: in blood mg %, before game	in blood mg %, after game	Difference	in urine mg %, before game	in urine mg %, after game	Difference	in sweat, mg
Goalkeeper...	355.5	348.0	-7.5	930.2	820.2	-110.0	105.5
Defense......	299.6	302.5	+2.9	904.6	780.2	-124.4	179.5
Offense......	308.2	300.1	-8.1	925.0	803.5	-121.5	257.9
Mean value...	308.7	305.7	-3.0	915.5	793.6	-121.9	213.6

Since the various soccer players exerted themselves in different degrees, we divided our findings according to three categories of players: goalkeepers, defense men, and offense men. As we see from Table 4, the changes in the blood chloride level cannot be shown to depend on the type of activity engaged in during the game. The urine chloride level is slightly depressed in the case of the goalkeepers and somewhat more markedly depressed in the case of the defense and offense players. The elimination of chlorides through perspiration is the sole quantity found to depend on the role of the player in the game: the goal-keepers, whose muscular exertion is slight, eliminate an average of 105.5 /468 mg, the defense men 179.5 mg, and the offense players, whose muscular exertion is greatest, 257.9 mg.

Each period of muscular exertion involves a loss of weight which occurs partly through the elimination of water by way of the lungs and sweat glands, partly through the giving off of CO_2, and partly through the disturbance (decomposition) of muscle matter. In the latter process, mineral substances, including NaCl are liberated from their bonds with muscle matter. All of these liberated substances enter the blood and lymph glands, producing an increase in osmotic pressure and the appearance of large quantities of ions in the blood. In view of this we concluded that a direct connection must exist between weight loss and the appearance of blood chlorides. The greater the weight loss, moreover, the larger the amount of chlorides in the sweat.

Finally, we compared the loss of urine chlorides with the chloride level in the sweat. Here too it was expected that the chloride level in the sweat would rise with increasing urine chloride losses, and vice versa. It turned out, however, that no such relationship could be discerned from the data: there were, in fact, cases where the chloride level in the sweat was high and the drop in urine chlorides slight. Reverse situations were also noted.

The diversity of the above results led us to perform a number of experiments using fixed trainer bikes in order to follow the path taken by the chloride variation curve in the course of work and for a time thereafter. Unlike Ewig and Wiener, who had their subjects exercise for 7 1/2 to 13 minutes to complete exhaustion, our exercise periods lasted from 45 to 60 minutes in order to approximate the conditions of such events as the 13.5-km foot race with respect to duration.

The results of the trainer bike experiments indicated that in four cases the chloride content of the blood drawn during the exercise period (after 32-36 minutes) had risen unmistakably , remaining unchanged in one case and dropping in another. In four cases the chloride level in the blood taken following the exercise period (48th to 64th minute) had fallen, while in two others it had dropped in comparison to its value at the start of the experiment. Blood /469

TABLE 5. THE EFFECT ON THE CHLORIDE LEVELS IN THE BLOOD, URINE, AND SWEAT AND OF THE LACTIC ACID CONTENT OF THE BLOOD AND SWEAT DUE TO EXERTION ON FIXED TRAINER BIKE

Subj. initial	Date of test (1929)	A	B	C	D	E	F	Amount of chlorides: in blood mg %	Amount of chlorides: in urine mg %	Amount of chlorides: in sweat mg	Amt of lactic acid: in blood mg %	Amt of lactic acid: in sweat mg	G
K.	Oct. 25	45	45	84	72	490	0	186	319	-	11	-	200
					-		32	185	-	-	24	-	-
					130		48	202	358	$\boxed{0}$	32	$\boxed{1615}$	65
					90		100	220	312	-	16	-	35
					72		220	213	-	-	10	-	-
K.	Oct. 30	45	45	90	60	700	0	302	607	-	12	-	490
					156		15	231	-	-	15	-	-
					150		35	220	-	-	21	$\boxed{1520}$	50
					-		50	227	444	$\boxed{536}$	15	-	80
					78		144	-	674	-	-	-	-
G.	Oct. 26	28	60	52	78	400	0	241	678	-	12	-	310
					?		36	227	-	-	10	-	-
					128		64	177	682	$\boxed{0}$	25	$\boxed{1010}$	90
					60		140	224	685	-	10	-	-
P.	Oct. 27	30	45	68	78	470	0	195	547	-	10	-	36
					-		34	238	-	-	13	-	-
					144		52	220	795	$\boxed{285}$	21	$\boxed{1326}$	70
					84		88	199	841	-	14	-	47
Ch.	Oct. 29	25	60	75	63	750	0	234	-	-	13	-	-
					-		32	238	-	-	29	-	-
					132		64	202	781	$\boxed{480}$	32	$\boxed{1560}$	-
					90		105	213	-	-	13	-	-
M.	Oct. 30	22	45	72	72	500	0	220	1100	-	10	-	115
					126		33	234	-	-	14.5	-	-
					150		49	202	1083	$\boxed{282}$	24	$\boxed{500}$	70
					81		129	222	-	-	20	-	-

$\boxed{}$ denotes the total content of chlorides and lactic acid accumulated in the sweatshirts over the total period of exertion.

KEY: A - Age in years. B - Duration of exertion, min. C - No. of leg motions per min. D - Pulse. E - Wgt. loss over period of exer. F - Blood sampling times, min. G - Amount of urine.

samples drawn still later (88th to 105th minute) indicated a rise in one case, a drop to normal in another, and in a third case a drop below the norm /470 (though to a higher level than in the foregoing case). The blood samples taken at the 129th, 140th, and 220th minutes indicated a rise in one case, a complete return to normal in another, and a return to approximately normal in a third. As regards the urine chlorides, they rose following cessation of exercise in one subject and dropped in the rest. The sweat of two subjects was found to be free of chlorides but to contain large quantities of lactic acid; in four other cases, however, the chloride content per sweatshirt varied from 282 to 536 mg. The lactic acid level in the sweat in the latter cases was likewise considerable (500-1615 mg).

Quite remarkable were the results of the experiments on subject K. performed on Oct. 25 and 30, wherein the chloride level in the blood lay below 200 mg (at 186 mg) in one case and at 302 mg in the other. Chlorides were completely absent from the sweat on the first occasion but were present on the second.

Comparing our results with those of Rakestrew, Peters, Talbert, Ewig, and Wiener, all of whom investigated the variation of the blood chloride level, we conclude that our findings are in agreement with those of the last-named authors. The findings of the first authors differ grossly - so much so, in fact, that Ewig and Wiener felt obliged to repeat the experiments. Rakestrew reported a negligibly slight rise in blood chlorides, Peters and others observed no change whatever, while Talbert and co-workers noted a slight rise.

Ewig and Wiener tested five persons for the effect of maximum exhausting exertion lasting from 7 minutes 30 seconds to 13 minutes 15 seconds. The first blood samples were drawn at the point of peak exertion, followed by others 10-

12 minutes following cessation of work, etc. At peak exertion they determined the average rise in the chloride level to be 351-383 mg. 10-12 minutes following the exercise, the chloride level was still higher than the norm, although the chloride curve had already dipped down. After 90 minutes, a drop from 398 to 388 mg was noted. In the remaining cases there was either a return to the original value or a maintenance of the elevated value.

Although the work performed by our subjects was much different from that in the Ewig-Wiener experiments both in regard to its intensity and its duration, it must be emphasized that we too noted both rises and drops in the blood /471 chloride level due to physical exertion. Our findings confirm those of our predecessors to the extent that we were able to discern a drop in blood chlorides under the influence of muscular exertion of greater duration.

The most thoroughgoing study of urine chlorides performed so far comes from the Fatigue Studies Laboratory in Boston. Talbott, Fölling, Henderson, Dill, Edwards, and Berggren made a series of precise observations of a single subject over a one-month period. The study began with a five-day control period which was followed by seven experiments involving exercise of varying duration and intensity performed on a treadmill and spaced over the period of one month. The authors found that chloride elimination by way of urine sank markedly on the working days. This finding corroborates our results with the cyclists, runners, and soccer players. Even though an increase in urine chlorides was noted in some of our subjects (in the trainer bike experiments, soccer, and foot races), we ascribed this to the absence of a strict dietary regimen such as that observed in the Boston study. In addition, such discrepancies in the results could have been related to variations in water and salt metabolism among individual organisms. The aforementioned U. S. authors concluded from their results that a weight loss of 1-2 kg through exercise is accompanied by a 2-4 g drop in urine chlorides.

Comparing our results with those of Snaper and Grünbaum, who tested the sweat of participants in the Amsterdam Olympic Games (soccer, crew, foot races, et al.) for chloride and lactic acid content, we see that marked changes in the amount of chlorides present in sweat do indeed occur as a result of muscular exertion. The difference between our findings and those of Snaper and Grünbaum lies in the fact that the sweat chloride level according to our data is lower than the lactic acid level. We, in fact, noted cases of lactic acid-containing, but chloride-free sweat. It is difficult to explain this discrepancy in the two sets of data, since the papers of Snaper and Grünbaum contain no mention of the diet of the Olympic athletes.

Talbert and Haugen established the existence of a direct relationship between the chloride levels in the blood and urine, although this relationship was not observable in every case. The chloride levels in the urine and sweat, on the other hand, seemed to bear no relation to each other. Our own results confirm the latter conclusion, but not the former. Talbert and Haugen unfor- /472
tunately do not mention the nature of the work performed by their subjects. They probably considered work not as a factor which affects salt metabolism in the organism, but as a mere diaphoretic. Their tables, for example, do not indicate whether the data they contain refer to experiments involving elevation of body temperature by warming or to those involving exercise. Moreover, the initial blood chloride levels vary only within a narrow range (330-390 mg).

In explaining the variation of the amounts of chlorides in the urine and blood under the influence of muscular activity as well as its relation to the sweat chlorides we emphasize that all work involves a loss of weight which is on some occasions significant (amounting to 4 kg in some participants in the 28-km foot race). This is accompanied by a rise in the mineral levels in the blood and lymph, with Cl ions responsible for major portion of this rise. Other factors to be considered are changes in osmotic pressure, alterations of water and salt metabolism, transfer of chlorides from the erythrocytes into the plasma, etc. Part of the water leaves the body with the breath, and another through the sweat glands. Such changes in the state of tissues and surrounding fluids lead to alterations in the uptake and release of various substances, including chlorides, by the tissues. Since the subjects in our experiments were athletes the state of whose organism was known to us only a short time before and after competition, and since the changes in blood and urine composition in the course of the day were likewise unknown to us, it is difficult for us to put our finger on the causes and sources of the manifold changes in chloride metabolism following muscular exertion. What does appear certain from a study we performed involving high- and low-chloride diets, however, is that the release of chlorides through perspiration requires a certain blood chloride level, and that this minimum blood chloride level varies greatly from individual to individual.

CONCLUSIONS

Muscular exertion produces the following variations in the chloride levels in the blood, urine, and sweat:

1. Two levels of blood chloride level variation are discernible. It rises shortly before the start or after the cessation of a short period of work, and drops after a longer period of exertion.

2. The urine chloride level generally drops. The amount of chloride /473
present in the urine usually increases at the start of work, however.

3. The magnitude of the drop in blood and urine chlorides stands in direct relation to the intensity and duration of exertion: with increasing intensity and duration of the latter, the blood and urine chlorides increase accordingly.

4. The sweat chlorides as a rule rise in the course of muscular activity.

5. When the blood chloride level is low, no chlorides are eliminated through the sweat.

6. Chloride metabolism during muscular activity is related to the general water and salt metabolism.

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Translated for the National Aeronautics and Space Administration by the FRANK C. FARNHAM COMPANY.